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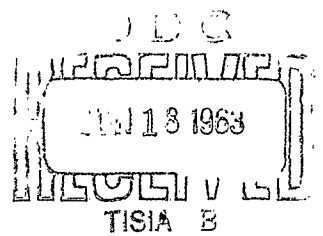
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THERMO ELECTRON

ENGINEERING CORPORATION

SECOND QUARTERLY REPORT
FOR
ADDITIVE CONVERTER STUDIES

By
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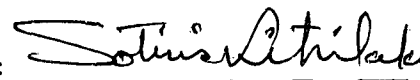
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Approved by:


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FOREWARD

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SUMMARY

This report outlines the progress of the Additives Research Program during the Second Quarter. The experimental apparatus and the testing procedures are described. An account of the cesium characteristics of the experimental converter is given and the correlation to other rhenium emitter diodes is discussed. The corrosion testing and plans for the next quarter are also included.



CHAPTER I

INTRODUCTION

The Additives Research Program is designed to be a parametric investigation of the effect on thermionic converter performance occasioned by the addition of cesium compounds of electronegative elements such as fluorine, chlorine, and oxygen to the test chamber. The program has evolved at a rapid pace since the publication of the First Quarterly Report.

For an experimental study of the changes due to additives on the performance of a thermionic converter it is first necessary to establish the correspondence of the cesium characteristics of the additive converter with the characteristics of other thermionic converters of similar design and materials. In this way differences in the output of the additive converter may be readily identified as being due to the additive and the results of different additive temperatures may be easily categorized.

For these reasons then the first part of the testing was concerned mainly with establishing the correspondence between the cesium characteristics of the additive converter and the cesium characteristics of previous rhenium emitter-molybdenum collector diodes.

It is also necessary to investigate the possible corrosive effects of the additives on the materials used in the construction of thermionic diodes. Five corrosion test diodes have been designed for this purpose and will be placed on life test. After a sufficient number of hours they will be opened and the diode components analyzed.



CHAPTER II

EXPERIMENTAL MATERIALS & APPARATUS

The additive converter which is pictured in Figure 2 of the First Quarterly Report was constructed, mounted in a vacuum system, and outgassed down to a pressure of 7×10^{-8} mmHg. After the completion of the experimental work on the vacuum characteristics the converter was pinched off from the vacuum system and the glass capsule containing the cesium broken. Next the cesium was distilled up the copper tube to the bend near the additive inclusion block, taking care that the bulk of the cesium condensed near this elbow and did not pass through the orifice into the test section. The tube containing the remaining glass particles was then pinched off. This completed the charging phase.

The converter was then mounted on a lead-through base plate for testing. The collector, cesium reservoir, additive chamber, and additive inclusion block were each provided with thermocouples and heating coils. The collector was also provided with cooling coils. A tungsten filament gun was placed above the emitter so that it could be heated by electron bombardment. Next, the assembly was placed on a vacuum system and connections were made to the power supplies for the heater coils, to temperature controllers from the thermocouples, and to the emitter filament.

Connections were made to the emitter and collector through an external sweep-monitor circuit. Observations of the output were made on an oscilloscope using for the inputs the potential directly across the diode and the drop across a calibrated shunt in series with the diode.

Finally, this test equipment was calibrated. The temperature regulators and their associated thermocouples were checked with a potentiometer. The pyrometer used for observing the emitter temperature was calibrated with a standard lamp. The necessary oscilloscope adjustments were made.



Figure 1a is a picture of the additive converter mounted on a vacuum system. Figure 1b is a picture of the experimental apparatus. On the left are the electron bombardment supply and the monitoring oscilloscope. In the center are the heater supplies and the temperature regulators. On the right is the additive converter.

Several more copper capsules containing cesium fluoride were also manufactured. The process consists in filling a four inch long, 3/16" O.D., copper tube with one gram of cesium fluoride. This fills the tube to about two inches from the bottom. The capsule is then wrapped with heating coils and evacuated. Following this the additive is baked at about 300°C until the pressure at the pump drops below 10^{-5} mmHg. Finally, the tube is pinched off above the level of the additive, and the capsule, after being work-hardened, is ready for insertion into the experimental converter.



CHAPTER III

EXPERIMENTAL RESULTS

1. BARE EMITTER WORK FUNCTION

After the converter was outgassed and before the cesium capsule was broken the vacuum characteristics of the diode were studied. Using the classical method saturation current measurements were performed for many different values of emitter temperature. I-V curves were plotted and the average bare work function of the rhenium emitter was determined. This information may be seen in Figure 2 of this report.

Figure 2 shows the bare work function of the rhenium emitter as calculated from Richardson's Equation, using for the saturation current density the intersection of the Boltzman line with the tangent to the saturated section of the I-V curve. The average value of five runs is 4.65 eV.

2. REPRODUCIBILITY OF CESIATED EMITTER

For the reasons given in the Introduction an experimental investigation of the cesium characteristics of the converter was undertaken. The resulting data was plotted on copies of former curves produced by rhenium emitter converters of similar design. Figures 3a, and 3b, show representative cesium data from the additive converter plotted on copies of previous rhenium emitter-molybdenum collector data for a two mil spacing.

In Figure 3a the emitter and collector temperatures for the previous runs were closely duplicated in the additive converter. I-V curves were then taken for several values of the cesium reservoir temperature. The same procedure was followed for Figure 3b. The cross-hatching in both figures denotes a scan in reservoir temperature. That is, the emitter and collector temperatures were



maintained at the required values and the reservoir temperature was allowed to cool over a range of 27 and 13 degrees respectively.

Typical pictures of the type from which the above data was taken are shown in Figures 4a, 4b, and 4c. Figures 4a and 4b show I-V curves taken at a constant cesium reservoir temperature. Figure 4c shows a scan of reservoir temperature over the range 596°K to 575°K. The area swept out by the I-V curve during cooling is clearly visible.

The close agreement of the additive converter cesium data with that of the previous data from converters of similar design and materials may be appreciated not only by the shape and orientation of the boundary curves, but also by a comparison of the difference of current densities at two cesium temperatures for a particular voltage. For example, from the additive converter data for Figure 3b it was found that at +.4 volts, $J_{Tcs = 596^{\circ}K} - J_{Tcs = 583^{\circ}K} = 8 \text{ amps/cm}^2$ which is very nearly equal to $J_{Tcs = 595^{\circ}K} - J_{Tcs = 582^{\circ}K} = 8.2 \text{ amps/cm}^2$ derived from the previous rhenium emitter data. The practice of matching differences of current density is a much more efficient and precise method of comparing data from two converters.

Due to the close agreement found between the two sets of data it will now be possible to make a quick and accurate evaluation of the effect of the additive on thermionic converter performance.



3. COLLECTOR AND EMITTER WORK FUNCTIONS

Besides the effect of the additive on the net output of the thermionic converter it is also important to know its effect on the work-function of the emitter and collector. For this reason some time was spent in taking runs suitable for the calculation of these quantities.

Figure 5 shows the results of the computation of the emitter work function from the saturation current. These points are plotted on a graph of the work function correlation to bare work function and the ratio of emitter to cesium reservoir temperature. Note that these points fall within the region of 4.54 to 4.74 eV bare work function shown in Figure 2.

Figure 6 is an example of an I-V curve taken to determine the collector work function. The value shown was determined from Richardson's equation using $V_B = \phi_c + V_o$ where V_B is the barrier voltage, ϕ_c is the collector work function, and V_o is the output voltage.

Figure 7 is a diagram of electron potential energy for a thermionic converter operating in the retarding region. ϕ_e and ϕ_c are the emitter and collector work functions respectively. V_o is the output voltage and V_B is the total barrier voltage. J_B is the Boltzman current density related to the barrier by the Richardson relation:

$$J_B = 120 T_e^2 \exp\left(\frac{-V_B}{kT_e}\right)$$

This is the model upon which the collector work function is based.

4. CORROSION TEST

To date parts for five corrosion test vehicles have been completed. Two of these have been fully constructed and outgassed. Cesium and cesium fluoride capsules have been inserted into the converters and they have been mounted on vacuum systems. The necessary heating and control apparatus has been provided. The life testing of these two diodes will have commenced by the time this report is published.



The other three corrosion vehicles are in the process of construction and will be used for testing cesium oxide and cesium chloride.

The above material represents the accomplishments of the second quarter of the Additives Research Program. At the end of the cesium testing the fluoride capsule was cracked and a control thermocouple and heater coil attached. Testing on the effect of the additives is now underway.

In addition to this the parts for a second additive converter to be used in conjunction with either cesium oxide or cesium chloride has been completed.



CHAPTER IV

PLANS FOR NEXT QUARTER

The testing with the fluoride has now commenced and will continue during the coming quarter. Data on the effects of the additive will be available very soon. The second testing stage, using cesium chloride, should also commence during this quarter.

The corrosion testing will take place during the first few weeks of the third quarter and the results of the analysis should also be available by the end of the third quarter.

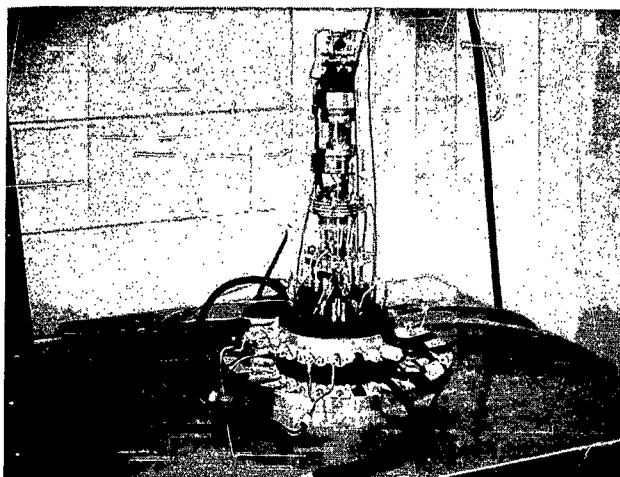


Figure 1a Additive Converter

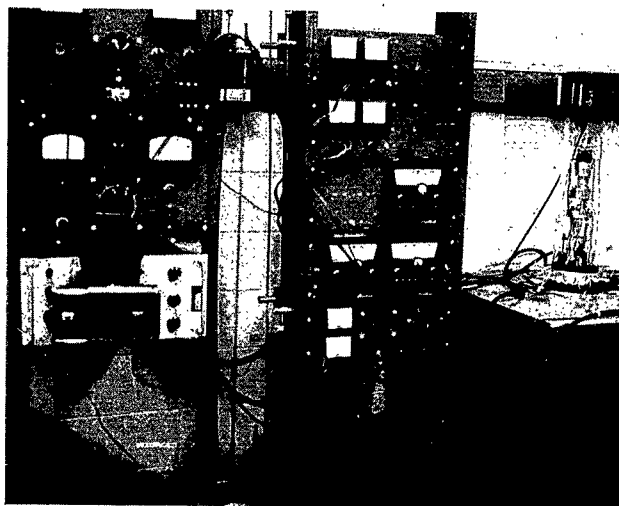
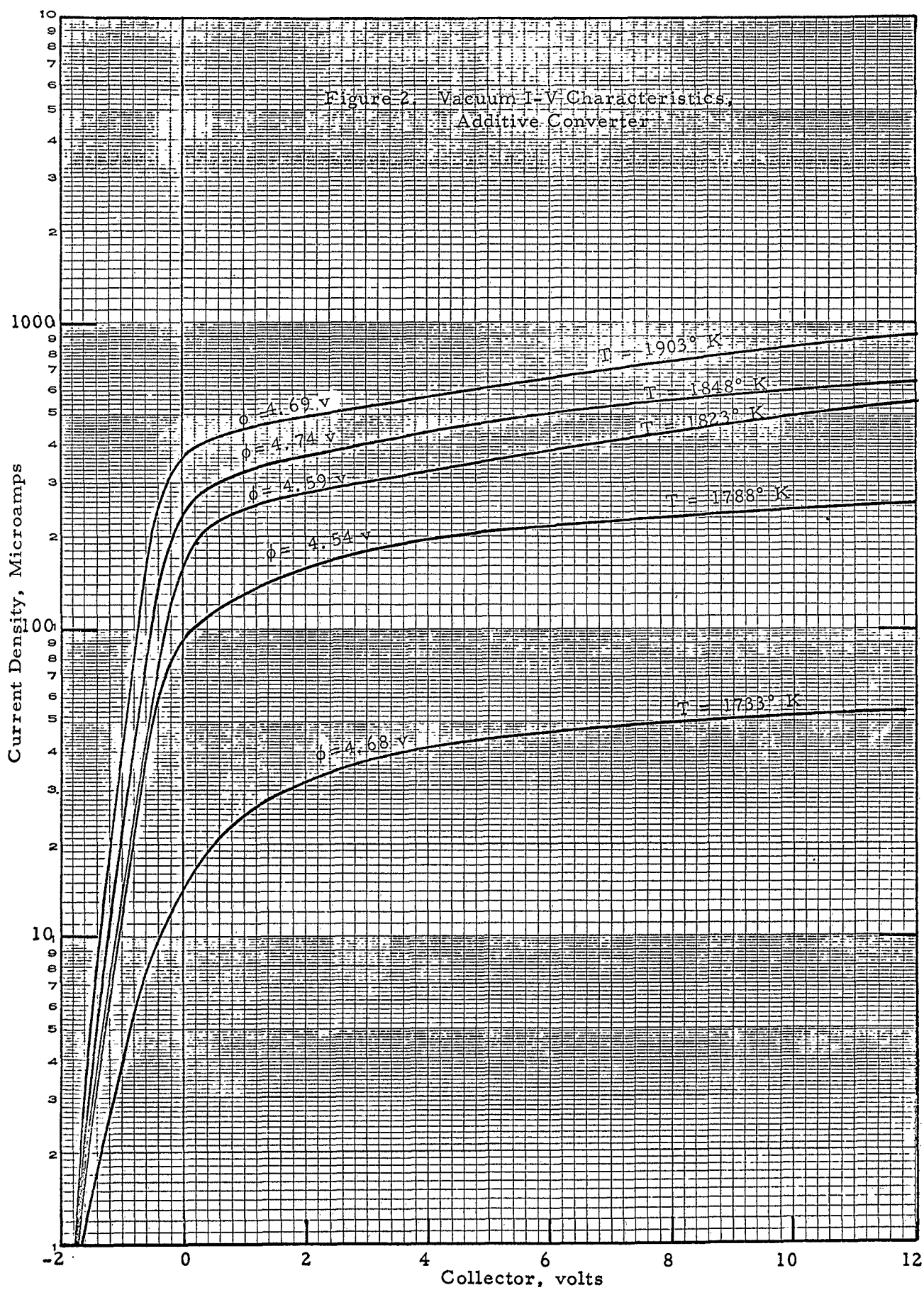


Figure 1b Experimental Apparatus

Figure 2. Vacuum I-V Characteristics,
Additive Converter



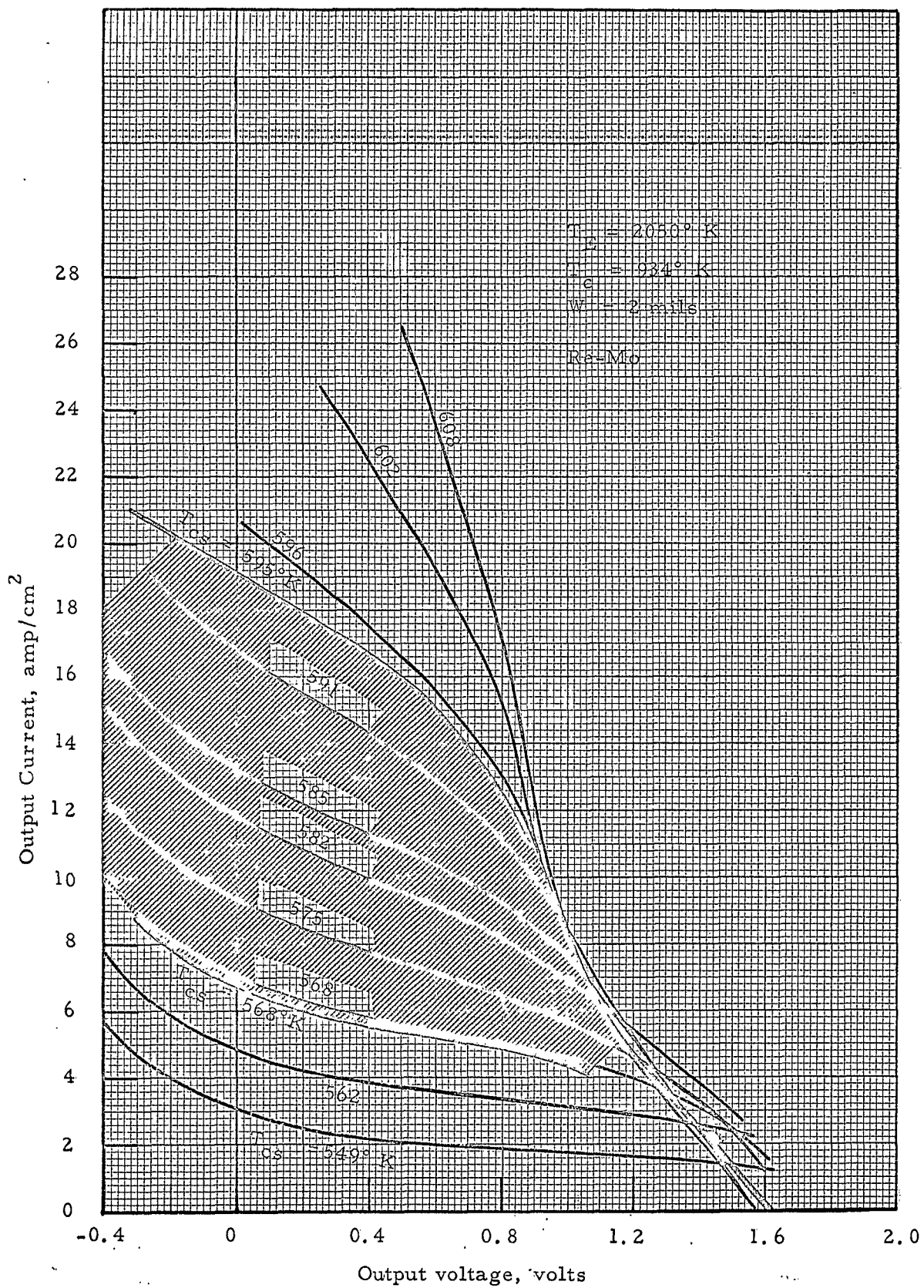
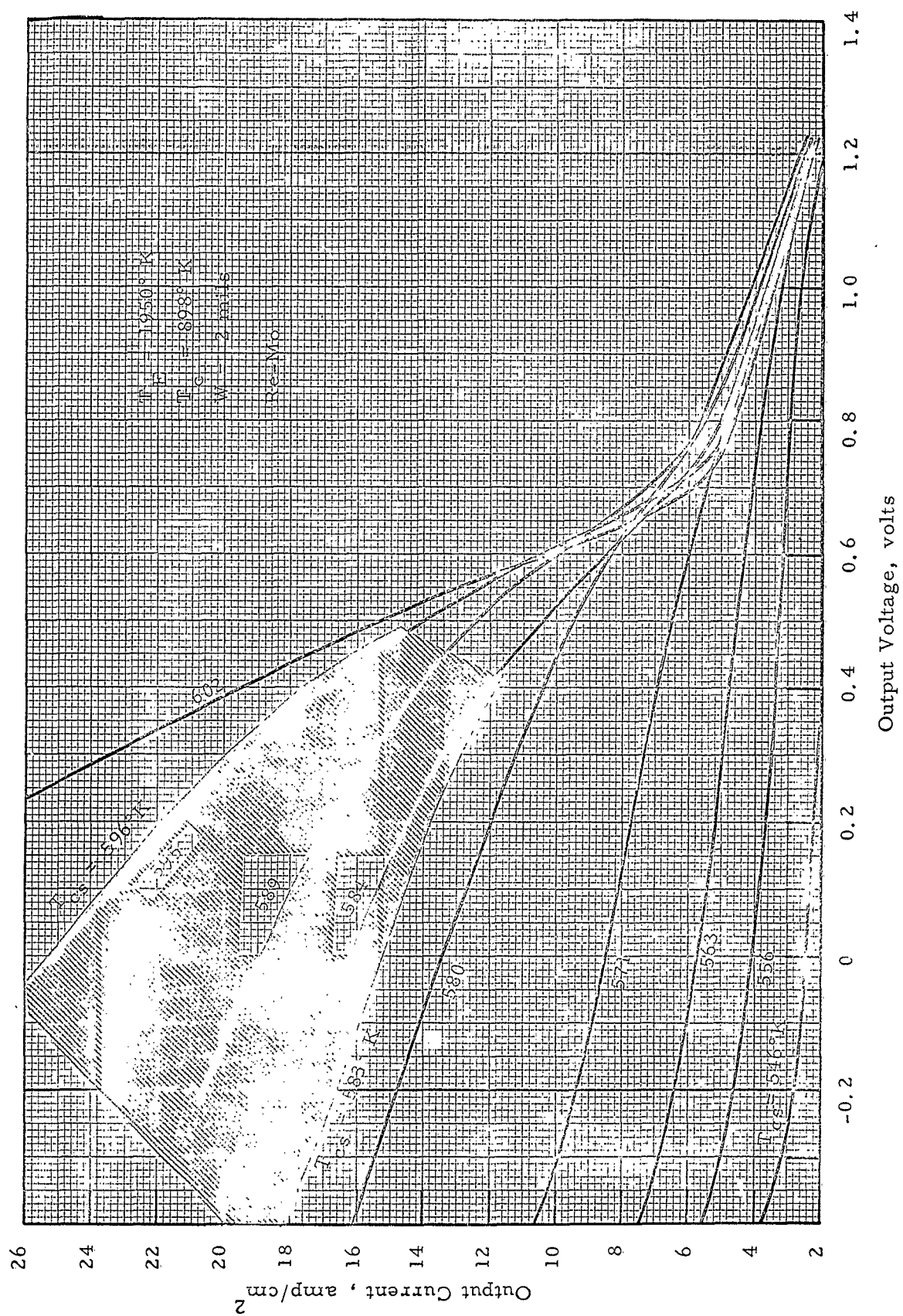


Figure 3a.



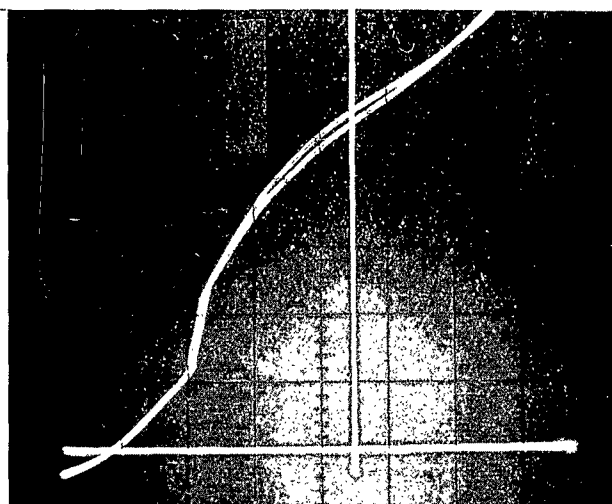
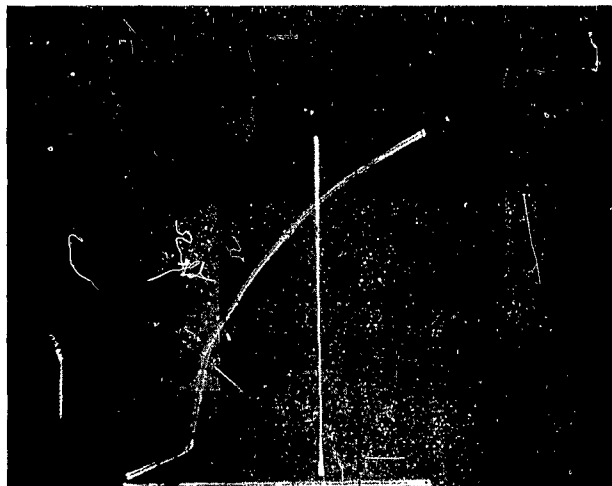


Figure 4 (a & b) Prints of Cesium Data From
Additive Converter

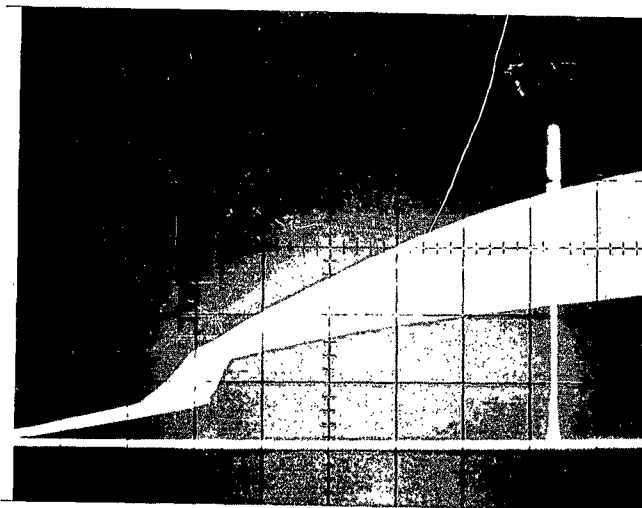


Figure 4c (Print of Cesium Data From Additive Converter)

Figure 5, Emitter Work Function Based on Sample I-V Curves

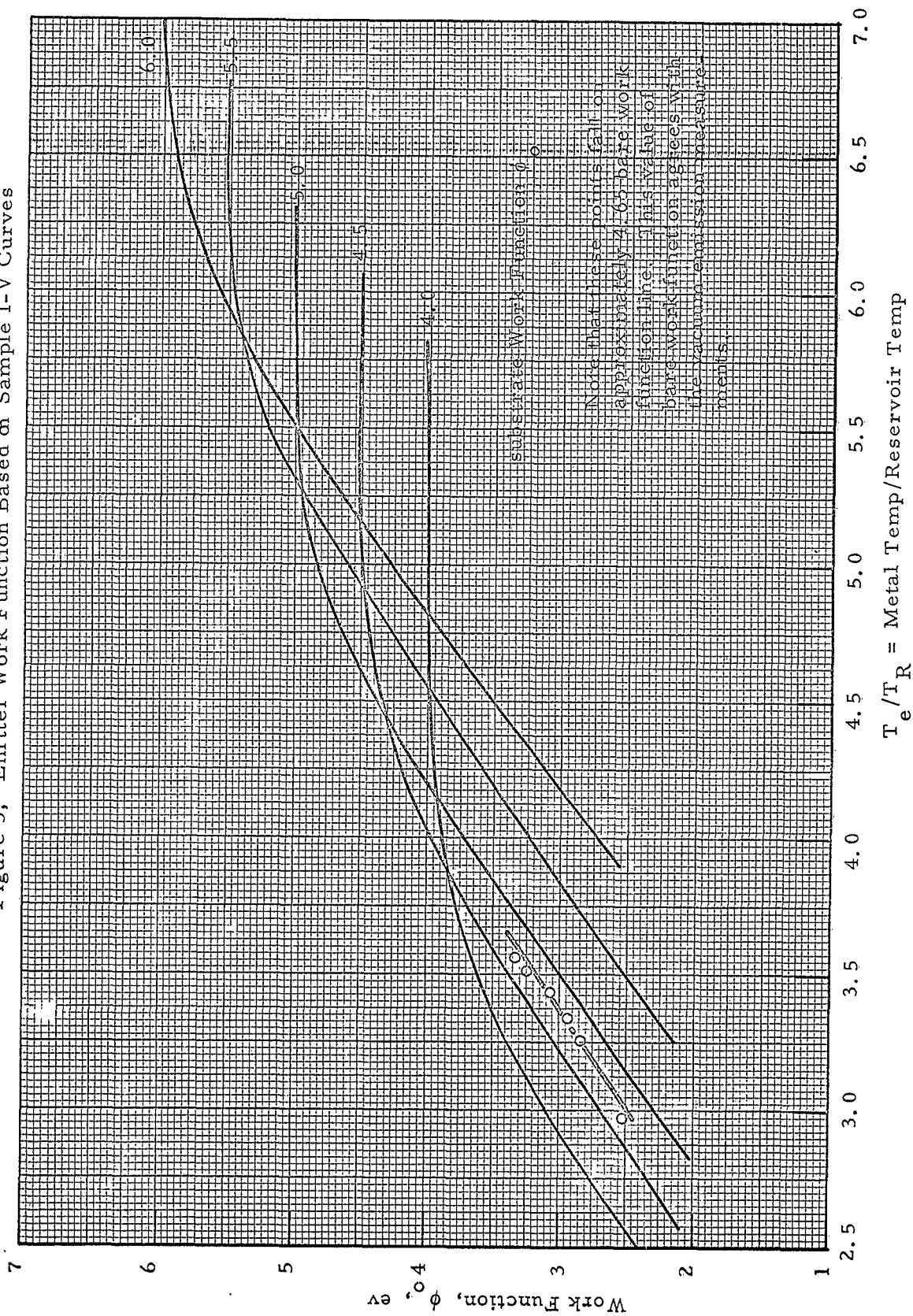
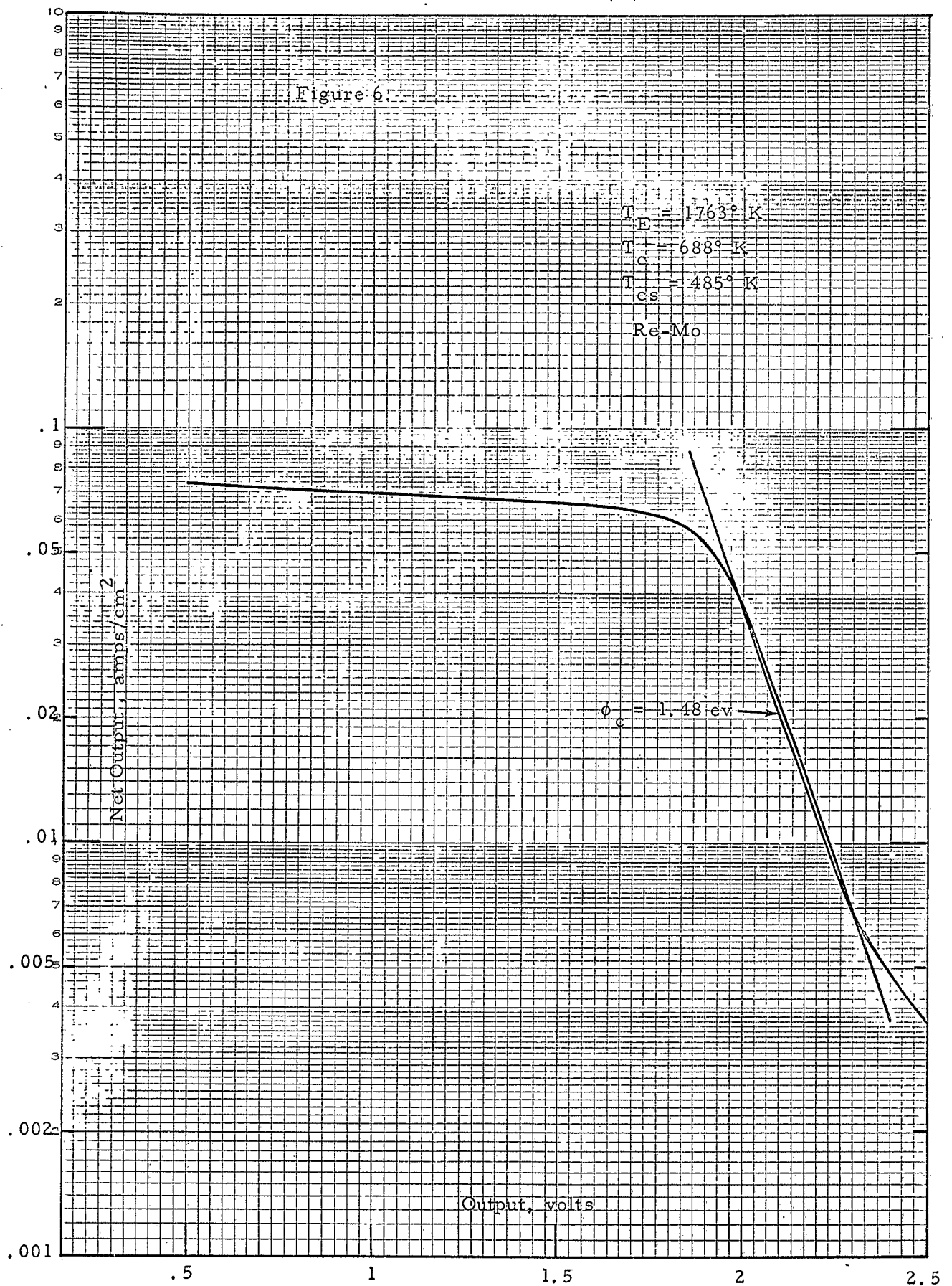


Figure 6



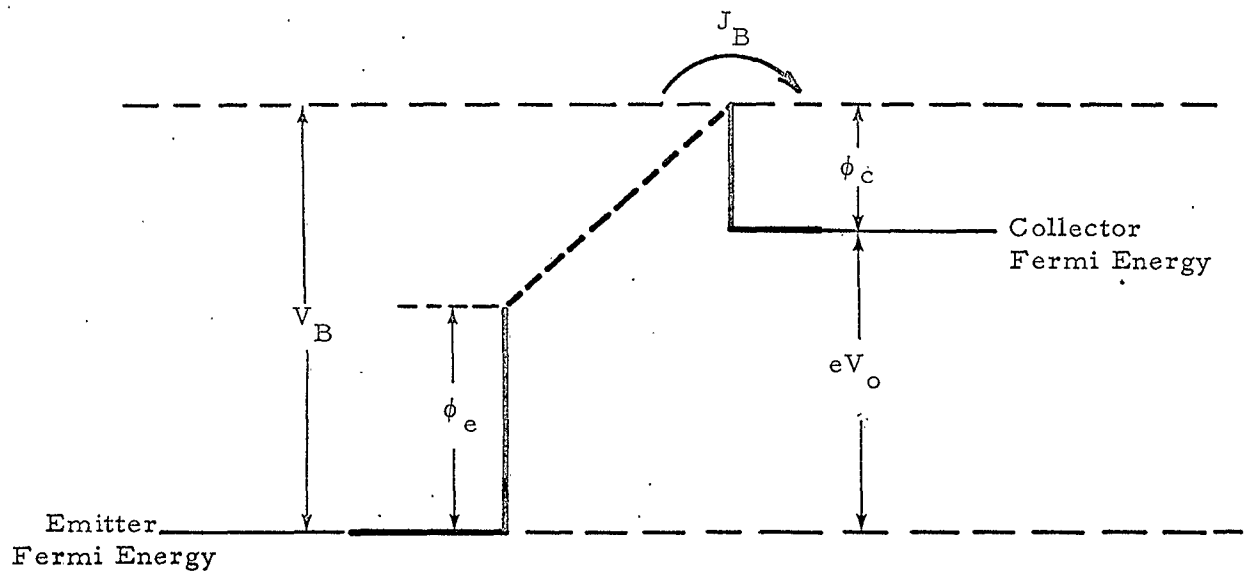


Figure 7. Electron Potential Energy Diagram for a Thermionic Converter operating in the Retarding Region

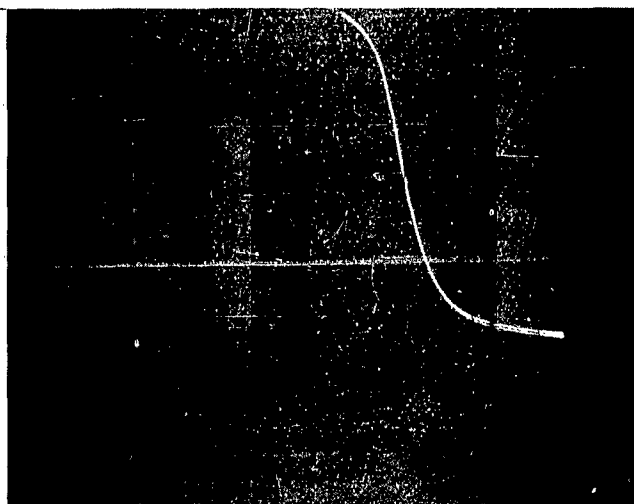
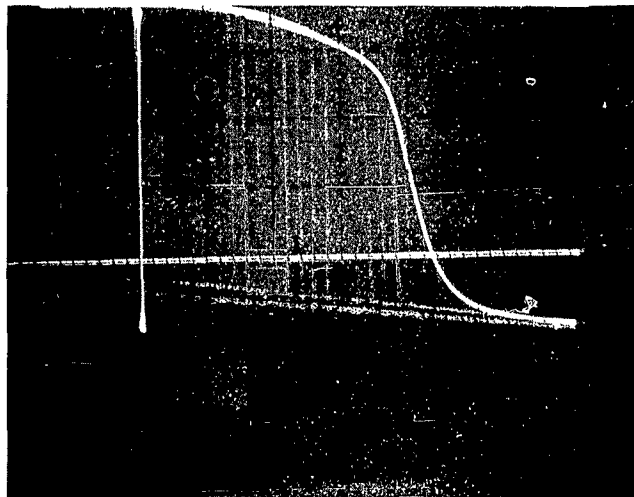


Figure 8 (a & b) Prints of Collector Work
Function Data

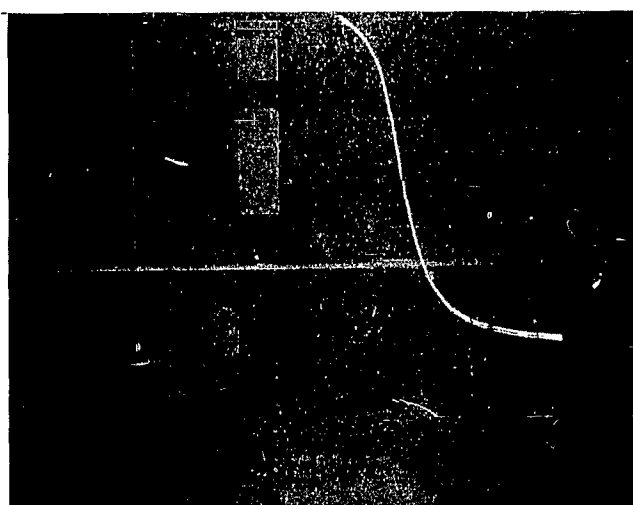
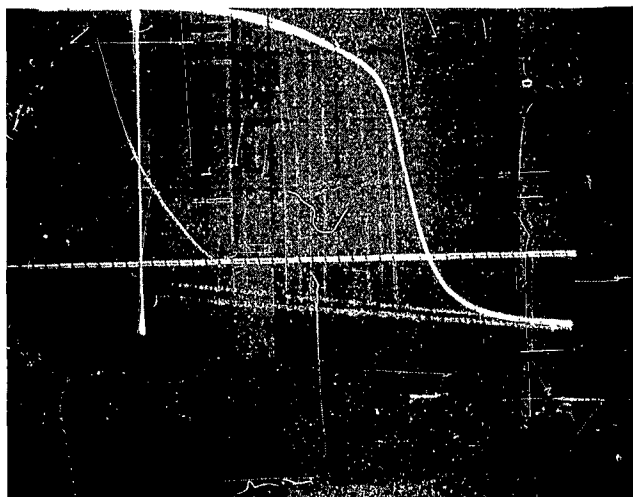


Figure 8 (a & b) Prints of Collector Work
Function Data

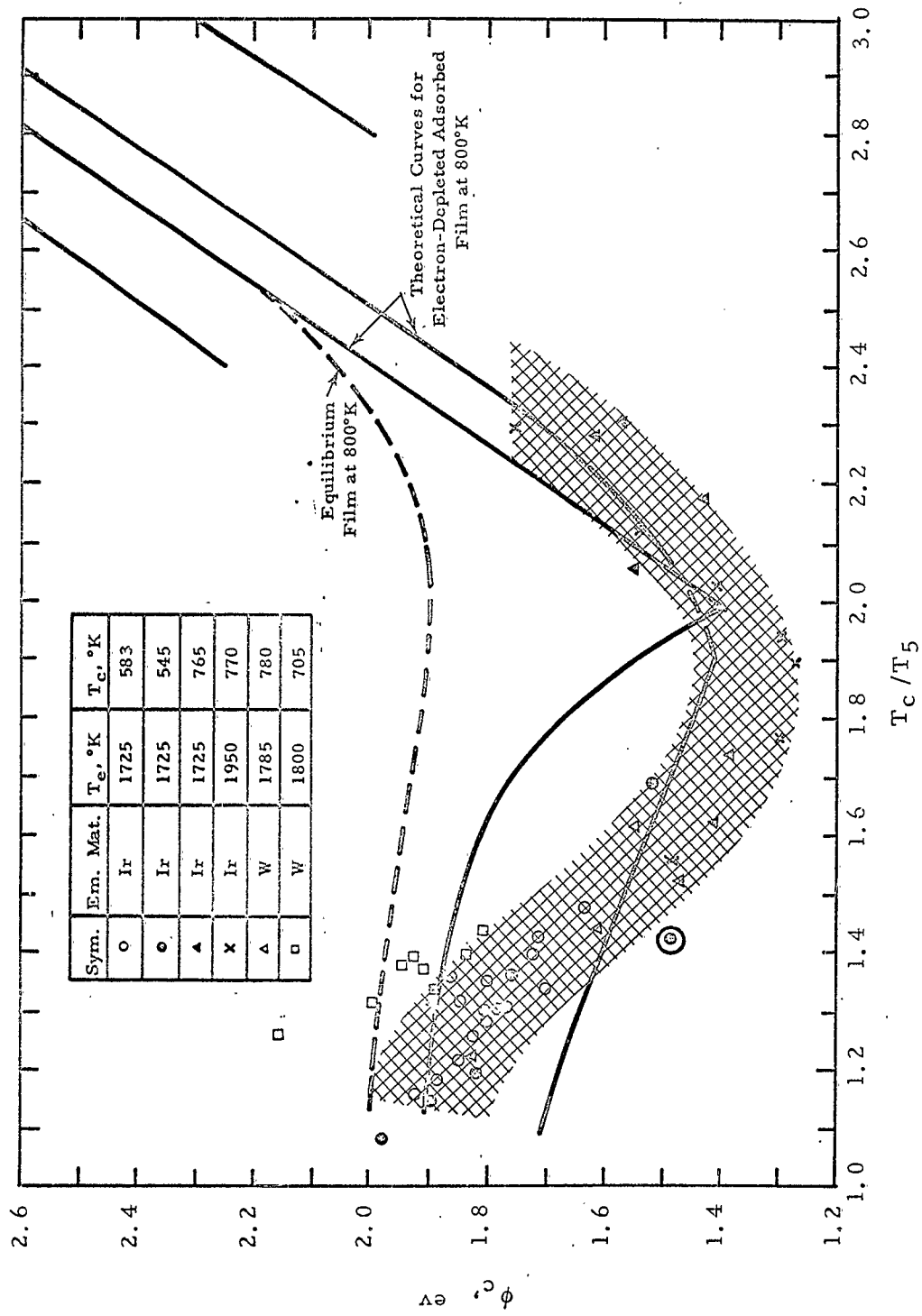


Figure 9. Compilation of Molybdenum Collector Work Function Measurements



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